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Attfield, Simon ORCID logoORCID: <https://orcid.org/0000-0001-9374-2481> and Baber, Chris (2017) Elaborating the frames of data-frame theory. Gore, Julie and Ward, Paul, eds. NDM13 Naturalistic Decision Making and Uncertainty: Proceedings of the 13th International Conference on Naturalistic Decision Making, 20-23 June 2017, Bath, UK. In: 13th Bi-annual International Conference on Naturalistic Decision Making (NDM13), 20-23 June 2017, University of Bath, Bath, United Kingdom. ISBN 9780861971947. [Conference or Workshop Item]

Final accepted version (with author's formatting)

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Elaborating the Frames of Data-Frame Theory

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ABSTRACT

As an explanation of sensemaking, data-frame theory has proven to be popular, influential and useful. Despite its strengths however, we propose some weaknesses in the way that the concept of a 'frame' could be interpreted. The weaknesses relate to a need to clearly contrast what we refer to as 'generic' vs. 'situation-specific' belief structures and the idea that multiple generic belief structures may be utilized in the construction of embedded situation-specific beliefs. Neither weakness is insurmountable, and we propose a model of sensemaking based on the idea of spreading activation through associative networks as a concept that provides a solution to this. We explore the application of this idea using the notion of activation to differentiate generic from situation specific beliefs.

KEYWORDS

Sensemaking.

INTRODUCTION

A good deal has been written about sensemaking, including various empirical studies and models. Notable accounts include Russell, Stefik, Pirolli and Card's (1993) Learning-Loop Complex; Weick's (1995) account of sensemaking in organisations; Pirolli and Card's model of sensemaking by intelligence analysts and Klein, Phillips, Rall and Peluso's (2007) Data-Frame theory. Each aims to capture something important about sensemaking with implications for how we might understand it better and perhaps how we might better enable it.

Inevitably, theories and methods for studying how people do sensemaking have tended to focus on analysis of post-hoc accounts of particular kinds of activity. While this has provided insight into the ways people develop understanding of complex situations, it may also limit it. And so we feel that there are gaps in the theoretical frameworks which result in methodological problems for analysis which are worthy of exploration. Any model of course, is a more or less useful approximation of what really goes on. Guided by the spirit philosophical pragmatism captured in Box's aphorism, "All models are wrong but some are useful" (1976) we aim to take a fresh look at sensemaking and develop on existing ways of thinking about it.

Our thinking references the data-frame model of sensemaking (Klein, Philips, Rall & Peluso, 2007), since this represents an important and influential model and one which attempts to engage with underlying cognitive processes of sensemaking, as we wish to. We will begin by developing an initial perspective on what sensemaking is, with an approach which has its roots in ordinary language philosophy. The approach is to develop a view of sensemaking based on considerations of the use of language surrounding sensemaking. From this we develop a view of sensemaking as seeking coherence between beliefs at different levels of abstraction about a domain. Following an overview of data-frame theory, we then introduce some empirical and theoretical reflections which may challenge our ways of thinking about sensemaking. From this we develop a new model which regards sensemaking as a process of developing interconnected networks of beliefs.

WHAT IS SENSEMAKING? - AN ORDINARY LANGUAGE APPROACH

To ask, 'What is sensemaking?' is to ask 'What is the meaning of the word 'sensemaking'? We consider this question from the perspective of ordinary language philosophy. In his *Philosophical Investigations* (2010) Wittgenstein said that, "For a large class of cases--though not for all--in which we employ the word "meaning" it can be defined thus: the meaning of a word is its use in the language." Thus, if wish to understand the meaning (of at least some) words, we must look at how the word functions in language. The motivation is to resist a temptation of an idealised yet nonetheless stipulated language, and to do this by examining the conceptual structures that are shown in language use. What this gives is a methodology for researching meaning through ordinary usage; an approach pioneered by ordinary language philosophers in the Oxford tradition such as Gilbert Ryle and J.L. Austin. For us, it also suggests that the concept of 'sense' has to be derived from the experiences and language of the people who we are studying and working with, rather than being imposed from some external source. While the NDM community would find this point self-evident, it is worth pointing out because some of the representations used later in this paper could be misread as imposed (a posteriori by the researchers) rather than derived from the words, beliefs and experiences of subject matter experts.

Sensemaking seeks coherence

One immediate difficulty is that the verb ‘sensemaking’ is not part of common usage - it is itself a stipulated term. But we do talk about things ‘making sense’ and ‘not making sense’. We explore this with an example (which we treat here as data). In the book, *13 Things that Don’t Make Sense* (Brooks, 2009), the author relays a discussion between Marie Curie, Hendrik Lorentz and Albert Einstein about how radioactive materials apparently defy the laws of conservation of energy and momentum. Brooks explains that, “Radioactivity was an anomaly; it didn’t *make sense*. The problem was eventually solved by the birth of quantum theory” (our italics). Without understanding the laws of conservation of energy and momentum or quantum theory, we can at least understand the initial problem as one in which there was a lack of consistency or coherence (we will stick with ‘coherence’) between beliefs about phenomena at two different levels of description. On the one hand, there is the description of the behaviour of radioactivity, whilst on the other hand, there are the laws of the conservation of energy and momentum. We can assume that the laws predict that radioactivity would behave in one way, whereas radioactivity actually behaves differently—hence, there is a lack of coherence between two beliefs. We can also assume that this lack of coherence is resolved once quantum theory is introduced.

Our next case is a thought experiment. Imagine you have a friend who you have learned enjoys museum visits - he visits many and talks about them frequently and you notice museum guides on his bookshelves. But, on a trip to a different city you see him turn down a trip to a local museum on the grounds that it sounds dull. This behaviour doesn’t make sense to you. Here, your theory about your friend is playing a similar role to the laws of the conservation of energy and momentum in the previous example and his behaviour is playing a similar role to the behaviour of radioactivity. The theory doesn’t predict the behaviour; it predicts something different. Again, the problem is one of coherence between beliefs at different levels of description. At one level we have your theory which is intended to subsume certain kinds of behaviour and at the other level an observation of behaviour which is inconsistent with it. There is a lack of coherence. We are likely to say that the behaviour doesn’t make sense in the light of the current theory/model. It’s not until you realise that your friend’s interest is limited to natural history museums (the offer related to a cultural museum), that correspondence is resumed. His behaviour can now be said to ‘makes sense’, but notably, not because the behaviour changed.

We note that the two examples above deal with what we will refer to as retrospective sensemaking, that is to say, they relate to things that have been observed and the way that they can be accounted for or subsumed within prevailing theories that ought to apply. We suggest a working definition of ‘sensemaking’ as a process of reasoning about information to construct a view (belief, representation, understanding) about some situation and then testing this view for coherence with other beliefs that one holds at different levels of description. In brief, sensemaking is a quest for a coherent belief set. This is in contrast to any notion of truth. The question about whether something makes sense is not a question about whether it is true or not, although we assume that coherence here could be said to act as a proxy for truth, since incoherence can be assumed to indicate falsehood. However, in a more pragmatic sense, coherence provides the basis for selecting a course of action that feels appropriate for that situation. Thus, the burden of proof is much lighter than for a test of ‘truth’ per se.

DATA-FRAME THEORY

As an explanation of sensemaking, data-frame theory (Klein, Philips, Rall & Peluso, 2007; Klein, Moon and Hoffman, 2006a & b) has proven to be popular, influential and useful. It is a theory of how understanding (and also misunderstanding) of aspects of the world occurs, evolves and changes. It provides a high-level account of the types of process that sensemakers need to perform and illustrates how these processes interconnect. The model is informed by studies of military operations, navigation incidents, intensive care nurses, fire-fighters, weather forecasters and navy commanders (Klein, Philips, Rall & Peluso, 2007).

The theory distinguishes two kinds of entity which interact during sensemaking: data and frame. Data are aspects of the world which a sensemaker experiences. A frame is a representation in the mind of the sensemaker which stands for the situation, for example, a doctor’s beliefs about a patient’s medical condition, a pilot’s understanding of location and heading, or a warship captain’s beliefs about the position, heading and intent of an approaching aircraft. The frame acts as both interpretation and explanation of the data by accounting for it within a more integrated and complete picture. Importantly, the frame extends beyond the data, using background knowledge and expectations to fill gaps, or rather, it creates gaps in which data can be accommodated.

Klein, Philips, Rall & Peluso (2007) suggest that frames take a number of forms, including stories, explaining the chronological and causal relationships between events, maps describing locations and directions, or plans describing a sequence of actions. The term frame is intended as a synthesis of various concepts which have been used previously in accounts of human understanding, including frames by Goffman (1974), Minsky (1974), scripts by Schank and Abelson (1977) and schemata by Bartlett (1932), Neisser (1976), and Piaget (1952, 1955).

The theory presents sensemaking as a process of framing and re-framing in the light of data. As we encounter a situation a few key elements, or anchors, invoke a plausible frame as an interpretation of the situation. Active exploration guided by the frame then elaborates it or challenges it by revealing inconsistent data. By extending further than the data, a frame offers an economy on the data required for understanding, but also sets up expectations. Hence a frame can “direct” information search and in doing so reveal further data that changes the frame. An activated frame acts as an information filter, not only determining what information is subsequently sought, but also affecting what aspects of a situation will subsequently be noticed.

Important to the selection of a frame is the sensemaker’s repertoire of frames and this underlies a distinction between experts and novices. It is argued that whilst experts and novices reason using the same procedures, experts have richer repertoires of frames that are better differentiated, allowing sense of a greater variety of situations, to be more precise about the situations, and to focus on fewer (but higher level) elements in a given situation (Lipshitz et al., 1997). Klein, Philips, Rall & Peluso (2007) also argue that frame activation depends upon the sensemaker’s ‘stance’ including factors such as workload and motivation, and their current goals.

GENERIC AND SITUATION-SPECIFIC BELIEF STRUCTURES

The first issue we raise concerns a distinction we want to make between what we will refer to as generic and situation-specific belief structures. By generic belief structures, we mean something like a conceptual repertoire. Generic belief structures amount to a set of preformed and general ‘understandings’ that a sensemaker can bring to situations to help them make sense of them. For a doctor, this might include a set of medical conditions and their features; for a football coach it might include ‘set plays’ and strategies. This repertoire is key in determining what a sensemaker can ‘see’ in a situation and hence, in part, defines their expertise. It is a repertoire of categories (possibly with labels) and their associations that is an abstraction from experience, or perhaps acquired through training and acculturation. It is a theory about things that *can* happen.

The idea of situation-specific belief structures is of a set of non-generalised beliefs about a specific situation; it is a situation picture. Situation-specific belief structures occur through information or ‘cues’ from a situation combined with the application of generic belief structures to form an interpretation of a prevailing situation. This is ‘comprehension’ or interpretation with all the associations and expectations that the application of generic belief structures can invoke. A situation-specific belief structure is a theory about a prevailing situation with part of that theory being that the application is correct. In this sense, it has a truth value. It is an interpretation of a situation which can be true or false. In contrast, a generic belief structure is neither true or false in the same sense. A generic belief structure isn’t a theory about a given situation but a theory about possible situations.

This distinction, of course, is not new. Data-frame theory has its roots in schema theory and here the distinction is made. Rummelhart (1980) (for example) makes it in his account of Schema Theory, describing schemata as generic data structures that represent generic concepts in memory, and distinguishing this from instantiations of schemas which occur when a situation is interpreted as an instance of a concept. He gives the example of buying something as an instantiation of a general purpose BUY schema. We prefer the term belief structure to schema since this avoids commitment to the idea of a simple mapping between situation-specific belief structures and generic belief structures. Situation-specific belief structures are complex. Below we develop the idea of multiple generic belief structures contributing to the construction of a given situation-specific belief structure. However, we argue that these two ideas are somewhat conflated in accounts of data-frame theory, and yet they are important to maintain as separate parts of a theory of sensemaking. One reason in particular that they are important to maintain, is that an account of the role of expectations and expertise in sensemaking depend upon it.

EMBEDDED BELIEF STRUCTURES

The distinction between generic and situation-specific belief structures helps us to develop the next idea, which is that the construction of situation-specific belief structures (or ‘situation picture’) can utilize multiple generic belief structures, applied opportunistically, to provide sense to a situation. Our suggestion arises from our own empirical studies and in part from experiences in using data-frame theory for analysing qualitative protocols.

In one study, a group of university librarians performed an information task using a document information visualisation tool called INVISQUE (reported in Kodagoda et al., 2013). With INVISQUE, searches are submitted to a canvas style interface and results are presented as visual objects that resemble index cards. These appear in groups or ‘clusters’ that the user can re-group and sort as they wish, using both manual and automated sorting functions. The system could be described as a spatial hypertext (Marshall, Shipman & Coombs, 1994). The system was loaded with a set of ACM SIGCHI conference papers and participants were asked to identify at least three influential authors in the field of information visualization (for them, an unfamiliar domain). The purpose of the study was to observe how users might appropriate the tool to conduct the task.

In a later paper (Kodagoda et al. 2016), we used data from this study to experiment with using data-mining for inferring users' sensemaking actions from system log data. We coded think-aloud protocols recorded during the task with events described by the data-frame theory (e.g. connect data to frame, elaborating the frame, questioning the frame etc.). Our initial attempts at coding presented a difficulty. We had asked participants to draw conclusions about authors based on information about papers. In order to do this, participants had initially to draw conclusions about papers, using cues such as citation count and publication date. They then used assessments of 'influential papers' to make inferences about the standing of their authors.

During the analysis, the following two think-aloud extracts were coded as 'connecting data with frame':

"I probably have a look at the overall paper. Ah interesting... has a heavy citation count."

"Back to Stuart K. Card again, Stuart K. Card seems to have a reasonable distribution. He is clearly highly cited. So we going to go with Card."

The frames, however, are of different types. The first appears to be an 'influential paper' frame, and the second appears to be an 'influential author' frame. They relate to different kinds of generic belief structure. This is not to say that one might not support inferences about the other, but that they correspond to different concepts.

In a study of military signals intelligence (Attfield et al., 2015; Wheat, Attfield & Fields, 2016), analysts were required to make inferences about the identity and locations of military units based on intercepted radio communications. They used features such as call frequency to make inferences about the radio model and combined this with communication content to make inferences about the kind of unit communicating. From this they were able to make inferences about their regiments and divisions. Each step appeared to be a sensemaking exercise in itself exploiting background knowledge (i.e. generic belief structures), and at each step the sense that was made provided a cue for the next, ultimately contributing to a complex situation picture (or situation-specific belief structure). Wheat, Attfield & Fields (2016) analyse these chains as 'inference trajectories', and consider the overall situation picture as a meta-frame consisting of a number of sub-frames.

In a study of corporate lawyers conducting e-discovery investigations on large email collections, Attfield & Blandford (2011) reported that the lawyers mapped out an investigated domain using extensive chronologies constituted out of episodes and events each of which may draw on generic belief structures at different levels of scale or granularity. These could range from the events and activities involved in an investigated company bidding for a contract to individual meetings with arrangement discussions, participants, locations and follow-up actions. Pennington and Hastie's 'story model' (1981) makes similar observations of jurors making sense of evidence in criminal cases by building situation-specific belief structures in narrative with these utilizing episode schemas. Selveraj, Attfield, Passmore & Wong, (2016) describe how a group of police crime analysts used 'think-steps' - a series of extensible templates that they use to decompose cases of different types (such as people trafficking and murder) into elements, and how these provided a structure for storing and visually representing data, generating requests for information, focussing research, structuring mental simulation, and reporting.

Finally, in work on intelligence analysis (Baber et al., 2015; 2016), suggested that analysts tend to alternate between broad and narrow focus, i.e., looking at several topics and then narrowing to a smaller number. Similar effects have been observed by Elm et al. (2005) and Roth et al. (2010). For this paper, the argument is that the broad/narrow focus represents effort toward the development of situation-specific beliefs (particularly through the use of 'working representations' that people construct to visualise the links between information). Coherence testing of situation-specific beliefs arises through the development of explanatory stories which allow generic beliefs to be applied to scrutinise the expectations and assumptions that the situation-specific beliefs imply.

The idea of comprehension as involving multiple schemas is described once again by Rummelhart (1980) who describes something akin to the paradox of the hermeneutic circle in the simultaneous interpretation of parts and wholes of objects. He explains this using the example of the interpretation of an image of a face. In the image there are marks that represent a nose, some lips, an eye, an ear etc., only they cannot be interpreted independent of the interpretation of face. Conversely, the interpretation of a face cannot occur without a certain interpretation of the parts. He points out that we presumably have a schema for each component (nose, lips, eye, ear etc.) and a schema for the whole (face) and that evidence for nose contributes to evidence for face and vice versa, and that these are all have a role through processes of inference in the interpretation of the picture.

Data-frame theory seems to say little about how frames might embed within each other in the construction of sense and how this might be a helpful way to think about the sensemaking process. Possibly, an explanation lies in the type of sensemaking situation that motivated that theory (i.e. military operations, navigation incidents, intensive care nurses, fire-fighters, weather forecasters and navy commanders) which we assume are more situated in action and time-critical. In more slower paced sensemaking tasks, such as intelligence analysis, e-

discovery and crime analysis (*i.e.* the ones that motivated the issue here), sensemaking presumably extends over longer periods and involves greater use of external representations as aids for memory and collaboration, and therefore we assume, the construction of more complex situation-specific belief structures. We think it is helpful, in understanding these kinds of sensemaking scenario to think about situation specific belief structures as having the potential to instantiate or utilize multiple generic belief structure in their construction.

AN ASSOCIATIVE MODEL OF SENSEMAKING

Following these reflections, we develop our case further by proposing a way of understanding sensemaking as the application of associative networks. If one assumes beliefs to be held in a structure in which associations between different belief objects can be usefully represented as links between nodes, then one can assume that activation of one node could lead to activation which spreads through the network. This raises several questions which are relevant to our discussion. For example, how are nodes defined and how are they linked?

How is the network structured and where is the activation spreading?

In the original conception of spreading activation (*e.g.*, Collins and Loftus, 1975), ‘knowledge’ was described as stored in a semantic network. This provided a clearly defined structure in which properties of a category could be decomposed into subcategories. For example, <animal><mammal><dog><retriever><golden>. This implies that the ‘meaning’ of each word in the category could be related to other words by the semantic properties of the words themselves. The represented propositions were analytic, in the sense that they were true in virtue of meaning. When one of the words in the network is activated, *i.e.*, when its level of excitation rises from resting level because it has been read, heard or spoken, this rise in excitation spreads to words connected to it. The spread is limited by distance, so closer words receive higher excitation than words which are more distant.

Amongst the initial successes of this approach was a plausible explanation of phenomena such as semantic priming effects (in which seeing or hearing related words would reduce the recognition time of subsequent words). The semantic structure was replaced by the late 1970s with forms which were defined by synthetic conceptual relations *i.e.* things that just happen to be the case. This is the basis of the concept map and is illustrated by figure 1 (constructed using the CMap tool). This shows concepts related to a ‘Point of Entry’ (or means of breaking into a house) for a domestic burglary and could be a possible concept map held by a Scene of Crimes Officer attending a crime scene. In concept networks, activation can still be assumed to spread between connected nodes. Thus, in figure 1, if an <openable> point of entry has been <broken / smashed>, then there might be <blood, DNA, etc.> that can be recovered as <evidence>.

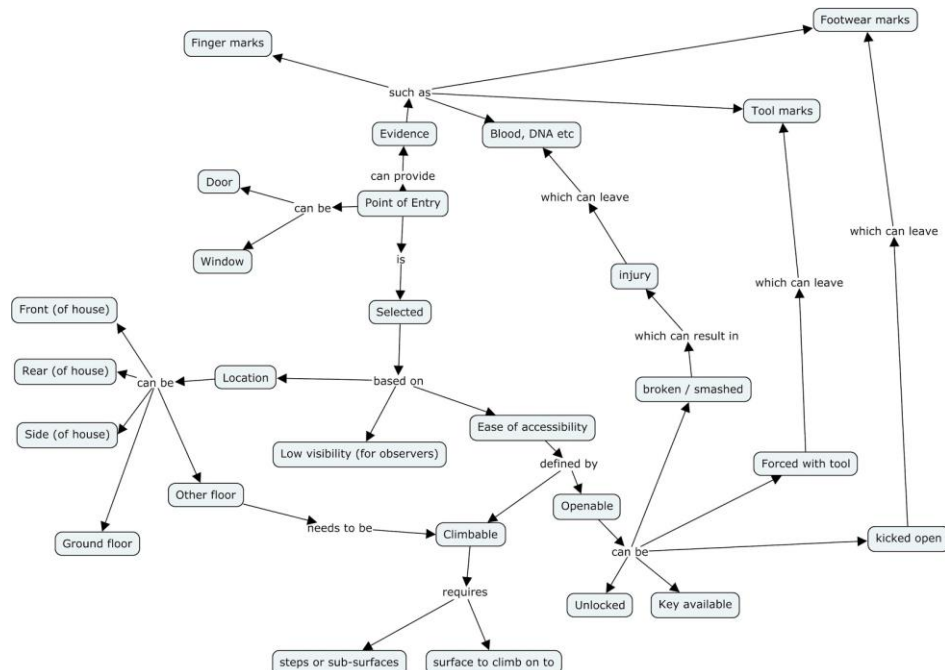


Figure1: A concept map as relevant to a ‘Point of Entry’ (or means of breaking into a house)

A concept map could represent the generic belief network of an individual. Furthermore, one could assume that each node could have differing levels of resting activation which would reflect prior experience and domain expertise. For example, figure 1 could be a concept map for a Crime Scene Examiner but could also be appropriate for an experienced burglar. Resting activation of specific nodes could differ between these individuals, *e.g.*, the burglar might have higher resting activation for nodes relating to ‘low visibility’ and ‘ease

of accessibility'. The CSE might have higher resting activation for nodes relating to 'evidence'. Thus, generic beliefs could be represented by an associative network with differing levels of resting activation on the nodes.

In terms of situation-specific beliefs, the concept map would be read as partially activated. In other words, assume that all of the nodes in the concept map have a level of excitation which was zero. In this case, the generic belief network would not be immediately accessible to conscious awareness. A would-be burglar, intent on breaking into a house, is walking down a street. In order to meet this intention, the would-be burglar would need to have 'point of entry' activated, which then leads to spreading activation to location, ease of accessibility and low visibility. So, these elements become a frame by which the situation can be judged. Whether these elements define a 'plan' for information search (*i.e.*, a conscious engagement with the activation of the elements) or whether they become a 'lens' for perception-action coupling (*i.e.*, a preconscious adaptation to environmental cues) is an important distinction in how sensemaking activity is performed. We feel that the NDM community tends to concentrate on the former while missing some essential aspects of the latter.

DISCUSSION

It feels credible to us that, rather than holding background knowledge in a single concept map, individuals would have a range of smaller, associative networks which are linked by 'weak ties'. In this case, the activation of nodes could be interpreted as expectations for more information. If all of the expectations are met, *i.e.*, if all of the associated nodes become active, then 'sense' is made. In this instance, coherence involves the confirmation that background knowledge is appropriate to the given situation. If their expectations are not confirmed then additional action is required. For us, this additional action takes the form of situation-specific beliefs. In this case, contextual features (which might be emotional, physical, kinaesthetic etc.) could become activated in response to a given situation. This could involve the gradual activation of nodes associated with a given context, perhaps through the sort of Q-learning mechanisms discussed in Baber *et al.* (2015). To this end, the spreading activation need not commit the person to a fixed structure or to the need to follow rules in order to amend the structure. Intriguingly, this suggests that classroom learning which reinforces semantic knowledge only partially develop concepts and that there is a need to put the person in situations in which the associated contextual information (including emotional response) could also be learned.

Sensemaking is the process of aligning situation-specific and generic belief networks. From this, discrepancy between generic and situation-specific beliefs requires effort to reconcile beliefs and this is where sensemaking occurs. This means that there is a continued need to apply coherence tests to the available information (in the situation-specific model) in terms of the belief networks that have been activated. For example, a smashed window could indicate an attempt to break into a building. However, if the glass is on the outside of the building, this would suggest that the break arose from actions inside the building (and could, perhaps, point to an attempt at staging a burglary for insurance purposes). In summary, we are proposing that a 'frame' can be considered as the activated portion of an associative network, and that it is likely that an individual will be using more than one associative network in a given situation. At the very least, the individual will have associative networks which represent generic beliefs, where the resting activation of nodes in these networks reflect prior experience of the individual, and another associative network that is constructed to reflect situation-specific beliefs.

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